

Engineering heart health: Biotechnology's innovation in cardiovascular disease management

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ABSTRACT

Cardiovascular diseases (CVDs) are a leading cause of death worldwide, presenting a significant challenge to healthcare systems. Recent advancements in biotechnology are transforming the management of CVDs, offering innovative solutions for diagnosis, treatment, and prevention. This review explores key biotechnological innovations, including gene therapy, regenerative medicine, precision medicine, and advanced diagnostics. Gene-editing technologies like CRISPR-Cas9 are promising in treating genetic cardiovascular conditions, while stem cell therapy and tissue engineering enable heart tissue repair. Precision medicine allows for more targeted treatments, and new diagnostic tools, enhanced by artificial intelligence, are improving early detection and risk assessment. Bioengineering has also led to the development of advanced cardiovascular devices, such as biocompatible stents and artificial hearts. Despite these advancements, challenges such as high costs, technical limitations, and ethical concerns remain. The integration of nanotechnology, 3D printing, and digital health tools could further revolutionize cardiovascular care. In conclusion, biotechnology holds immense potential to improve CVD management, reduce healthcare burdens, and enhance patient outcomes through personalized, innovative therapies.

Keywords: *cardiovascular diseases, CRISPR-Cas9, tissue engineering, artificial intelligence, nanotechnology*

INTRODUCTION:

Cardiovascular diseases (CVDs) refer to a variety of heart and blood vessel illnesses. Diseases of the heart muscle and the circulatory system that supply the heart, brain, and other essential organs are among the many conditions that fall under the broad category of cardiovascular disease (Pagidipati et al. 2013). They are a group of diverse illnesses, with atherosclerosis serving as the most common underlying cause. CVDs are long-term, asymptomatic conditions that progressively worsen throughout a person's life. Furthermore, the primary cause of illness and mortality among patients globally is CVDs (Sonja et al. 2014). Globally, atherosclerosis is the leading cause of death from cardiovascular disease. It is a thickening and hardening of the artery wall that occurs with aging and is linked to several disorders and has a significant negative influence on the cardiovascular system. The development of atherosclerosis is largely caused by elevated plasma cholesterol levels (>150 mg/dL) (Helvacı et al. 2019; Frak et al. 2022).

Globally, the prevalence of CVDs, the primary cause of premature death and disability in humans, is increasing. In addition to contributing significantly to the rising expenses of healthcare, CVDs have a significant socioeconomic impact on the general populace. Nearly all cardiovascular diseases have an underlying pathogenesis and progression that is primarily of atherosclerotic origin. This causes peripheral vascular disease, coronary artery disease, cerebrovascular disease, and venous thromboembolism, which in turn causes myocardial infarction, cardiac arrhythmias, or stroke. Lipid-lowering medications, antihypertensives, antiplatelet, and anticoagulant treatments are the main regimens for the prevention and treatment of CVDs, in addition to adopting healthy lifestyle choices. There are still large gaps in the treatment of CVDs, notwithstanding their efficacy (Flora et al. 2019).

The biggest cause of death, accounting for 17.7 million fatalities, is cardiovascular disease (CVD), which includes ischemic heart disease and cerebrovascular diseases like stroke. The World Health Organization claims that India is responsible for one-fifth of these deaths globally, particularly among younger people. India has an age-standardized CVD death rate of 272 per 100,000 people, which is significantly higher than the global average of 235, according to the Global Burden of Disease research. (Prabhakaran et al. 2016) Indians are afflicted with CVDs ten years before people in the West. The high mortality rate, quick progression, and early age of beginning of CVD are of great concern to us Indians. Indians are known to have the highest rates of coronary artery disease (CAD), and this elevated risk cannot be explained by the traditional risk factors (Sreenivas et al. 2020).

Cutting-edge biological therapies with the ability to repair and regenerate damaged cardiovascular tissues include gene therapy, stem cell therapy, and RNA-based therapeutics. Early findings are encouraging, indicating that these treatments could significantly alter the landscape of CVD treatment, even if they are still in different phases of clinical validation. The care of CVD is being revolutionized by cutting-edge medical technologies and gadgets, including wearable technology, minimally invasive procedures, and implantable devices (Di et al. 2024). By moving care from hospitals to homes, these developments improve patient outcomes and lower healthcare costs by enabling early diagnosis, ongoing monitoring, and efficient treatment. Thanks to genetic testing and biomarker identification, personalized medicine enables customized treatments that maximize therapeutic benefits and reduce side effects (Roth et al. 2020). However, there are a number of obstacles to the widespread use of these new treatments, such as ethical concerns, cost and accessibility concerns, and regulatory barriers. Accelerating the creation and application of novel treatments requires addressing these obstacles and encouraging interdisciplinary cooperation. The management of cardiovascular disease could be revolutionized by incorporating new therapeutic approaches into cardiovascular care (Singh et al. 2024).

Biotech advancements in cardiovascular diagnosis:

Recent biotechnological advancements have significantly enhanced cardiovascular diagnosis, making it more precise and non-invasive. Innovations such as genetic testing, biomarker discovery, and advanced imaging techniques like 3D echocardiography and cardiac MRI enable earlier and more accurate detection of cardiovascular diseases. Furthermore, artificial intelligence (AI) is playing a key role in interpreting complex data from diagnostic tools, aiding in the prediction of heart disease risks. These technologies are improving the ability to diagnose conditions like heart failure, arrhythmias, and coronary artery disease, thus allowing for better-targeted treatments and improved patient outcomes (Tique et al. 2024).

Nanotechnology: The therapy of cardiovascular illnesses, especially atherosclerosis and myocardial infarction, has shown great promise in the realm of nanotechnology. Targeted drug distribution made possible by nanosystems is a crucial feature that increases treatment efficacy and reduces adverse effects (Bonnet et al. 2021). Furthermore, by creating molecular imaging agents that selectively target atherosclerotic plaques, nanosystems aid in diagnostic imaging and make it possible to identify and diagnose severely sick locations (Mog et al. 2019).

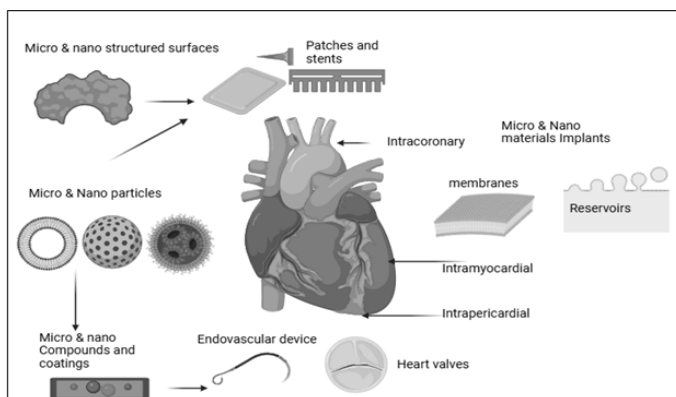


Fig. 1. Nanotechnology in cardiovascular diseases (Omidian et al. 2023).

Nano-based systems in Atherosclerosis: Bonnet et al. (2021) presented a study on nanosystem that made use of nano-emulsions of oil in water that were loaded with nanoparticles of superparamagnetic iron oxide. A human antibody (P3) functionalizes this nanosystem, allowing for targeted magnetic resonance imaging (MRI) of atheromatous lesions that pose a high risk. Additionally, it can deliver medications to atheromatous plaques, opening the door for non-invasive atherosclerosis imaging and treatment approaches.

Hu et al. (2022) investigated a unique nanosystem using PdH nanozymes that resembled tetrapod needles. Through ROS scavenging, hydrogen-based anti-inflammatory actions, and autophagy activation, these multifunctional nanozymes efficiently reduce inflammation and oxidative stress in arterial plaques. The study emphasizes the potential of developed nanomedicines in the treatment and management of atherosclerosis.

The development of lipid-core nanocapsules with anti-PECAM-1 on their surface and docosahexaenoic acid (DHA) as its nucleus allowed for targeted distribution to the inflammatory endothelium in atherosclerosis. Without compromising cell viability, the nanocapsules showed effective conjugation, an appropriate size, and cellular uptake. These results point to the created nanocapsules' potential for use in pharmaceutical treatments for atherosclerosis (De Castro et al. 2021).

Systems of biomimetic nanoparticles have been studied for the targeted treatment of atherosclerosis. Rapamycin-loaded PLGA nanoparticles coated with a macrophage membrane exhibit biocompatibility and specific binding to atherosclerotic lesions and activated endothelial cells. The nanoparticle technology demonstrated good safety profiles and prevented the advancement of atherosclerosis in animal models. For the treatment of atherosclerosis, biomimetic nanoparticles may be used as secure and efficient drug delivery vehicles (Wang et al. 2021).

PM@Se/Rb1 NPs, a biomimetic nanodrug delivery system, was created to specifically treat atherosclerosis. To improve plaque

stability, the method used ginsenoside Rb1 nanoparticles (Se/Rb1 NPs) and platelet membrane coating on selenium (Se). When paired with the anticoagulant medication warfarin, the PM@Se/Rb1 NPs had anti-inflammatory and anti-angiogenic properties, efficiently transported medications to plaques, and shown possible synergistic effects. This study demonstrates the potential of biomimetic nanodrugs and how they can be used in conjunction with clinical medications to treat atherosclerosis (Yin et al. 2022).

Gene therapy: In cardiovascular medicine, gene therapy has become a game-changing field that offers novel ways to treat complicated diseases like CVD. In order to modify gene expression and enable targeted therapeutic treatments, a variety of molecular tools have been created in this field. With the use of these advanced instruments, scientists can target particular genes, alter gene expression, and take molecular action, providing potential methods to lessen the underlying genetic causes of CVD (Cring et al. 2022).

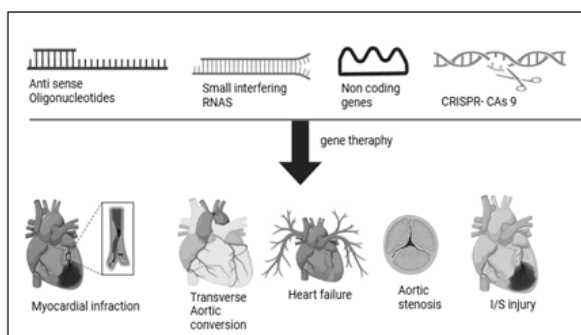


Fig. 2. Gene therapy for cardiovascular diseases (Crooke et al. 2017).

Antisense oligonucleotide: ASOs function to suppress the expression of a particular molecular target. They are composed of single-stranded DNA and usually contain 13–20 nucleic acids. This is accomplished by attaching itself to mRNA and creating a duplex that RNase H1 cleaves, which prevents the creation of proteins (Crooke et al. 2017).

Crucial cardiovascular trials have shown great promise for RNA-targeted ASOs, especially those that target Apolipoprotein C-III (ApoC-III) (Ramms et al. 2019). Triglyceride-rich lipoproteins are cleared more slowly when ApoC-III inhibits lipoprotein lipase (LPL), which raises the risk of cardiovascular disease. The first generation of volanesorsen, an ASO that targets ApoC-III, has been shown in clinical trials to be effective in lowering TG levels by up to 77% and 71.8%, respectively (Berthold et al. 2021). This suggests that individuals with hypertriglyceridemia may benefit from using volanesorsen. By efficiently lowering TG levels by 78%, GalNAc-volanesorsen, which is licensed in the EU for FCS, reduces the risk of acute pancreatitis. GalNAc-conjugated volanesorsen targeting ApoC-III has been investigated in clinical trials, with encouraging results in lowering atherogenic lipid profiles and enhancing safety profiles (Alexander et al. 2019).

A protein that is mostly produced in the liver, angiopoietin-like 3 (ANGPTL3) is a unique genetic target for lowering the risk of CVD since it is essential in blocking endothelial lipase and LPL (Li et al. 2020). The lipid profile of individuals with familial mixed hypolipidemia was effectively recreated by a GalNAc-modified ASO in phase 1 research, suggesting the possibility of therapeutic mimicry. ANGPTL3 suppression significantly reduced ApoB, ApoC-III, non-HDL-C, and VLDL-C. Inhibition of ANGPTL3 was investigated for clinical safety in a phase 2 experiment (NCT03371355) (Minicocci et al. 2013). Multiple doses resulted in a maximum 63% reduction in TGs and a 36.6% reduction in non-HDL-C levels, according to a phase 1 study conducted in humans (Akaumianakis et al. 2021).

Small interfering RNA (siRNA): The potential of chemically produced or recombinant siRNAs to initiate RNA interference and use the RNA-induced silencing complex (RISC) molecular machinery was investigated. From the first lipid-mediated transfection reagents to more sophisticated formulations, the administration of these treatments has changed throughout time (Ranasinghe et al. 2023).

Over the last ten years, a number of pharmacological treatments for ATTR amyloidosis have been developed. In August 2018, the FDA approved ONPATTRO (formerly Patisiran), the first marketed siRNA (Kristen et al. 2019). Unlike its rivals that are GalNAc-conjugated, ONPATTRO has a different liver uptake mechanism. ONPATTRO, which is formulated as lipid NPs (LNPs), protects therapeutic oligonucleotides from being broken down by natural enzymes. The particle enters the liver by vascular fenestrations and attaches itself to LDLR on hepatocytes after being opsonized by apolipoprotein E (ApoE), which is produced from circulating lipoproteins (Akinc et al. 2019). ONPATTRO showed a safe and efficient decrease in serum TTR in phase 1 and phase 2 trials. Patients with ATTR-polyneuropathy were the subject of the phase 3 APOLLO study, which showed promising results for 126 patients with related cardiac dysfunction (Di Stefano et al. 2022).

The liver produces the majority of angiotensinogen (AGT), which has drawn interest as a possible target for cutting-edge antihypertensive treatments. In pre-clinical research and a phase 1 study, zilebesiran—the first siRNA created to lower AGT mRNA in hepatocytes showed effects exclusive to the liver (Matsusaka et al. 2012). Notably, four-part phase 1 research found that zilebesiran single doses resulted in clinically significant drops in both systolic and diastolic blood pressure that lasted for up to 24 weeks. The drug's effectiveness was demonstrated when the serum AGT decrease surpassed 90% (Desai et al. 2023).

Biomarkers: A biomarker is a “characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention” (Downing et al. 2001). Both the assessment of sickness and the creation of medication therapy for illnesses depend heavily on biomarkers. Biomarkers can even be useful in figuring out the precise dosages for any particular medicine in the latter stages of drug development. Biomarkers are also being regarded as surrogate end goals for therapeutic studies in more recent times (Dhingra et al. 2017).

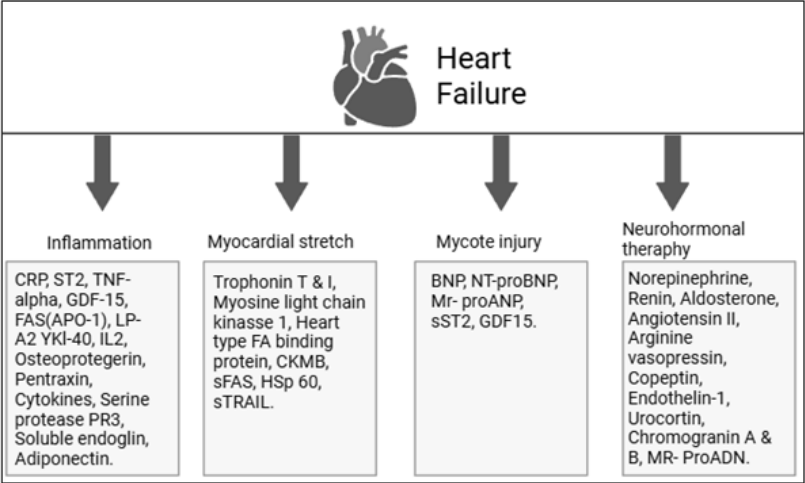


Fig. 3. Biomarkers for heart failure (Dhingra et al. 2017)

The following are the biomarkers used for heart failure:

Troponin I and T: They are cardiac isomers of the troponin-tropomyosin complex proteins, are released into the bloodstream by cardiomyocyte necrosis and are often helpful in identifying myocardial ischemia. Nevertheless, high-sensitivity Troponin T and I tests have been suitably investigated for the prognostication of patients with established heart failure and for the prediction of heart failure as they are also enhanced in the blood of patients with severe heart failure (Saunders et al. 2011; Xue et al. 2011).

Neutrophil gelatinase-associated lipocalin (NGAL): Renal tubular cells release neutrophil gelatinase-associated lipocalin (NGAL), another glycoprotein covalently bound to matrix metaloproteinase-9, in response to renal inflammation and injury. In the GALLANT trial, NGAL was also demonstrated to provide additional prognostic and diagnostic value in addition to BNP (Maisel et al. 2011).

Galectin-3: An intriguing biomarker, galectin-3 plays a crucial part in the initiation and control of cardiac remodelling and

fibrosis. On short-term follow-up, the blood Galectin-3 level in patients with acute decompensated heart failure has been demonstrated to be predictive of mortality. However, there is less evidence in the literature to support the independent use of Galectin-3 alone to predict prognosis in patients with heart failure (Van et al. 2006; Shah et al. 2010).

ST-2: The interleukin family (IL-33) receptor ST-2 has two gene forms: soluble (sST2) and transmembrane. Blood ST-2 levels have been demonstrated to predict mortality and new-onset heart failure, just as other biomarkers (Sanada et al. 2007). In patients with ST-elevation myocardial infarction, researchers have also looked at the predictive power of ST-2 levels in addition to other conventional risk markers including NT-proBNP levels. Additionally, it influences prognosis more so than conventional heart failure risk factors (Sabatine et al. 2008).

Mid-regional pro-adrenomedullin (MR-proADM): The existence of chronic heart failure is closely linked to higher levels of mid-regional pro-adrenomedullin (MR-proADM), a stable prohormone fragment of adrenomedullin, a vasodilatory peptide. It has been demonstrated that MR-proADM is more accurate than BNP and NT-proBNP at forecasting 90-day death in patients with heart failure and dyspnoea (Maisel et al. 2010).

Growth differentiation factor-15: Researchers have connected elevated levels of this biomarker, which is categorized as having anti-hypertrophic effects (apoptosis), to evaluate prognosis in patients with chronic heart failure and in community-dwelling adults as a predictor of all-cause mortality, including non-cardiovascular mortality, in addition to the data provided by blood NT-proBNP and C-reactive protein levels (Daniels et al. 2011).

Precision medicine: Through the use of “omics” in cardiology, precision medicine has the potential to completely transform the treatment of cardiovascular disease (CVD) in the future. It allows a doctor to treat heart conditions according to each patient’s particular profile. Here are the examples of Omic stratified literature on heart failure: Improved spironolactone

responsiveness in diastolic heart failure patients was associated with NR3C2, which codes for the spironolactone target protein, and CYP11B2, which is involved in aldosterone production. In individuals with transthyretin-associated cardiomyopathy, Tafamidis decreased cardiovascular event-related deaths and hospitalizations (Maurer et al. 2018). BAG3 and CDKN1A are linked to LV systolic dysfunction, while loci KLHL3 and SYNPOL2-AGAP5 are implicated in HF. Numerous processes that contribute to the evolution of heart failure are impacted by spiro lactone. Patients with heart failure can have their 5-year all-cause mortality predicted by copeptin (Glick et al. 2013). A CA125-guided diuretic approach increased eGFR in patients with acute heart failure and renal dysfunction, and CA125 is a proxy of fluid overload, making it potentially useful for directing decongestion treatment. Those with AHF have high levels of hs-cTnT. Whether at baseline or peak, a rise in hs-cTnT is linked to adverse outcomes, particularly cardiovascular mortality at 180 days. The long-term trajectory of cardiac troponin T (cTnT) and N-terminal pro-brain natriuretic peptide (NT-proBNP) in older persons without HF can predict systolic dysfunction, incident HF, and CV mortality (Sethi et al. 2023).

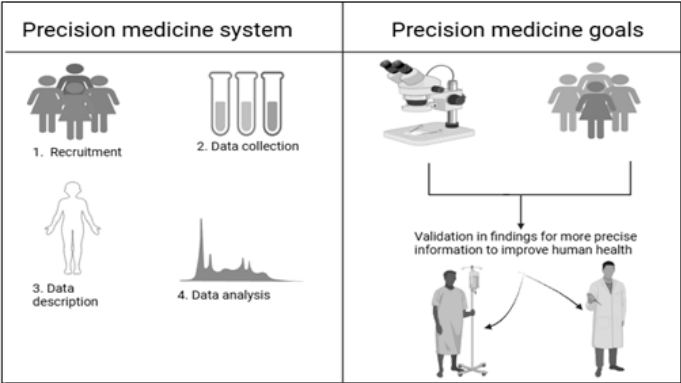


Fig. 4. Precision medicine (Bamba et al. 2024).

Cardioinformatics: Cardioinformatics is an interdisciplinary area that uses computational biology and bioinformatics techniques to store, compute, and analyze data related to

cardio- (vascular, renal, and metabolic) diseases. In order to meet clinically unmet requirements, cardioinformatics techniques can assist medical practitioners in comprehending the connections between cardiovascular health and other physiological systems. They can also offer insights into how to diagnose, treat, and manage these complicated disorders more efficiently. In order to gain new insights into the underlying causes of cardio- (vascular/renal/metabolic) diseases and to increase the accuracy of diagnosis and treatment in the clinic and at home (e.g., using wearable devices like continuous glucose or blood pressure monitors), cardioinformatics entails the collection, management, and analysis of large amounts of human and animal data (Khomtchauk et al. 2020).

Machine learning, artificial intelligence (AI), and other cutting-edge computational methods have frequently been used in cardioinformatics research to evaluate intricate biological data and create predictive models that can guide clinical judgment in real-world applications ranging from the identification of new drug targets to medical imaging (such as cardiac electrophysiology). To find effective, existing medications that could help patients with cardiovascular diseases or their related renal and metabolic co-morbidities (e.g., chronic kidney disease, type II diabetes, non-alcoholic fatty liver disease, etc.), for example, it has been common practice to use AI and machine learning techniques to search genome sequencing results and large drug-target databases (Tsao et al. 2023).

Similarly, in the context of routine medical practice and precision medicine, advances in cardioinformatics can help doctors and healthcare providers interpret different kinds of patient-centric data, such as genetic, proteomic, metabolomic, and imaging datasets (e.g., MRI, CT scans, echos). When combined, cardioinformatics aims to increase our quantitative knowledge of the cellular and molecular processes that underlie the pathophysiology of cardio-(vascular/renal/metabolic) diseases and to create more efficient data-driven approaches to their diagnosis, treatment, and prevention, which will ultimately improve patient outcomes (Khomtchauk et al. 2023).

Cardiovascular MedTech: The increasing availability of a wide variety of linked health devices holds great promise for revolutionizing CVD preventive and management tactics to enhance health outcomes and lessen the financial burden of CVD. In addition to prevention, disease management, patient involvement, self-care, and education, linked health technology for CVD also aims to enhance physicians' capacity to offer patient care through remote monitoring techniques and tools. Providing safe, efficient, individualized care at every stage prevention, early detection, diagnosis, treatment, and management is one of the main goals of this developing discipline (Wongvibulsin et al. 2019).

Cardiovascular MedTech advancements include minimally invasive treatments in addition to diagnostics. Smaller, more accurate tools have been made possible by the development of new materials and robots, which has sped up recuperation periods and allowed for less intrusive procedures. The creation of patient-specific implants and prostheses has been transformed by the use of 3D printing technology, providing customized solutions for challenging situations (Vento et al. 2024).

Wearable technologies: The capacity to continually measure and communicate important physiological data in real time is unparalleled thanks to wearable technology that is outfitted with advanced sensors. Utilizing wearable technology allows medical practitioners to get a thorough picture of the patient's vital signs, such as blood pressure, heart rate, and oxygen saturation, which promotes a more sophisticated and individualized approach to cardiovascular treatments (Guk et al. 2019). The Nexfin® makes use of "Nexfin HD," a non-invasive monitoring device that uses continuous pulse pressure to give precise and ongoing cardiovascular system evaluation (Ariturk et al. 2016). By employing a sophisticated oscillometric approach to identify changes in blood pressure, the Continuous Noninvasive Arterial Pressure (CNAP®) provides continuous and noninvasive arterial pressure measurement (Biais et al. 2010).

Robotic technologies: Cardiovascular procedures are now much more capable thanks to robotic technology, which

provide medical personnel more accuracy and dexterity. Procedures may be carried out more precisely by utilizing robotic help, enabling complex movements that were previously difficult with conventional methods (Chakravartti et al. 2019). The da Vinci Surgical System has transformed procedures including mitral valve repair and coronary artery bypass grafting (CABG). The overall effectiveness of these surgeries is increased by the system's robotic arms, which are operated by a surgeon and offer unmatched precision in navigating confined locations (Cerny et al. 2020). The incorporation of robotic technology into catheter-based therapies is best demonstrated by the Hansen Sensei Robotic Catheter System. By enabling very precise and controlled motions during operations such as catheter ablation for arrhythmias, this technology lowers the margin of error and enhances patient outcomes (Nazafi et al. 2023).

3D Printing technology: A revolutionary development in personalized medicine and therapeutic treatments is the use of 3D printing technology in the cardiovascular profession. This cutting-edge technology makes it possible to precisely fabricate anatomical models that are unique to each patient, providing physicians with essential resources for preoperative planning, medical education, and patient communication. For instance, bioprinting has not yet been widely applied in the field of cardiovascular medicine for a number of reasons. Creating sophisticated, hierarchical, and biocompatible artificial tissue constructions is currently the main application for the technique. Currently, training and preintervention planning are the primary uses of 3D printing in the cardiovascular area. Even while 3D printing makes it possible to create insightful anatomical models, it's important to keep in mind that most existing models are static and might not accurately capture the dynamic nature of either normal or diseased tissues (Bartel et al. 2018; Liu et al. 2021).

Novel materials: Cardiovascular devices with improved durability and customized biomechanical qualities may now be designed thanks to the discovery and integration of innovative materials including shape memory alloys and biocompatible polymers. For stents, grafts, and other

implanted devices to function as best they can and be biocompatible, certain materials are essential (Song et al. 2022). Advanced biocompatible polymers were used to create artificial heart valves, which are more adaptable and wear-resistant than traditional devices. These features lower the chance of deterioration and enhance the quality of life for individuals with cardiac valve disorders by enabling the valves to operate more effectively over time (Kumar et al. 2023). In order to meet the increasing need for appropriate replacements in patients with cardiovascular illnesses, vascular grafts and endovascular procedures composed of biocompatible and long-lasting materials are crucial (Fang et al. 2021).

Challenges and limitations: Even though nanosystems have a lot to offer in the areas of targeted drug delivery, cardiovascular disease treatment, and diagnostics, these issues must be properly taken into account and resolved for their effective clinical use. Shear-targeted drug delivery, magnetic delivery devices, and liposomes all exhibit promise, but further study is needed to maximize these strategies and guarantee the effective delivery of medications to the central nervous system. Improving penetration through the blood-brain barrier and overcoming microvascular dysfunction are two persistent issues that must be resolved to increase the effectiveness of nanosystems in the treatment of stroke (Omidian et al. 2023).

Low editing efficiency, a clear off-target effect, high toxicity and low tissue specificity of the delivery system, inadequate identification of the pathogenic genes of cardiovascular disease, and other flaws prevent gene editing therapy from being used clinically at this time (Cao et al. 2021). Despite providing real-time monitoring capabilities, wearable technology may face issues with data quality, dependability, and user adherence that might reduce its usefulness in therapeutic settings. To ensure dependability and safety, artificial intelligence must be thoroughly validated and seamlessly integrated into current healthcare operations, even while it holds promise for precise and customized therapies. Although robotic technology and minimally invasive techniques improve surgical precision

and lessen physical stress, they may also pose challenges for healthcare practitioners in terms of cost, accessibility, and the learning curve (Wongvibulsin et al. 2019).

To guarantee sustainability in healthcare delivery, it is critical to take into account the ecological and financial effects of these technologies. Furthermore, it is impossible to overestimate the importance of carrying out a large number of clinical studies in order to validate the safety and effectiveness of the suggested medical technology. These studies are necessary to guarantee the positive effects of these innovations on patient health and well-being and to provide evidence-based support for their broad adoption (Maddula et al. 2022).

CONCLUSION:

In conclusion, advancements in biotechnology are significantly transforming the landscape of cardiovascular disease (CVD) prevention, diagnosis, and treatment. Innovations in areas such as genetic engineering, tissue engineering, nanotechnology, and biomaterials are enabling more effective, personalized, and minimally invasive approaches to heart health. Promising developments, including targeted drug delivery systems, gene therapies, and bioengineered cardiac tissues, offer the potential to address the underlying causes of cardiovascular conditions and improve patient outcomes. Despite these advancements, challenges such as regulatory barriers, high costs, and the need for further clinical validation remain. Ongoing collaboration across disciplines—including engineering, biology, medicine, and regulatory agencies—is critical to maximizing the impact of these technologies. As research progresses, biotechnology has the potential to significantly enhance the management and treatment of cardiovascular diseases, offering hope for better heart health worldwide.

FUTURE PROSPECTIVES:

Unquestionably, genomics has sped up the process of identifying the mutations that cause heart disorders. Although the technology required to convert this data into clinical interpretation and practice is still difficult, the exploration of genetic sequences, gene assembly, and identification is still

developing and appears to have a bright future. The exome, or protein-coding DNA, is the subject of much research, but non-protein-coding DNA and its influence on significant clinical illnesses, which are mainly unknown, are also of interest in modern genetic sequencing. Given the chronic, multimorbid, and diverse character of cardiovascular illnesses and their slow development, precision medicine is the way of the future and has the potential to improve their care. These illnesses may start their etiology decades before they finally show symptoms. Because cardiovascular illnesses may be prevented, diagnosed early, and treated specifically, the application of precisely focused diagnostic and individualized therapy techniques can completely change management. Many of the technology required for the application of precision medicine are still in their infancy, and the discipline is still developing. Traditional cardiology has benefited greatly from these new methods in many areas, such as the pathophysiology, diagnosis, and treatment of diseases. The pathophysiology of cardiovascular disease has been better understood because to gene analysis and transgenic methods. Despite the current lack of clinical success, gene therapy and stem cell therapy have given scientists and doctors new ideas for treating cardiac disorders. Consequently, there is a pressing need for substantial and quick advancements in molecular cardiology. The creation of novel technologies in molecular and cellular biology is primarily responsible for these advancements.

Conflict of Interest

There is no conflict of interest related to the study.

Author contributions

Acquisition and interpretation of data is done by Dipti Das, Tanisha Bhowmick, Tiyasha saha. Conception, design and revising of the article are done by Rupesh Dutta Banik.

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